ENGG1500 Assessment 6 Title page

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Discipline: Medical engineering

Workshop class: Workshop number (not room) / Day / Time

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Team number: 13

How many hours did this assignment take: 30 hours

Who proof read this assignment before submission? And was it valuable?

My sister proofread and yes it was Valuable…………….. Yes/No

What mark would you give yourself? 25/30

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1.0 Abstract

Medical engineering is a fast and growing field of research providing new technologies and methods of treatment for all kinds of people with all kinds of medical complaints, diseases and conditions. With the average life expectancy in Australia steadily increasing over the past 20 years, there is now more emphasis placed on improving the quality of life during these latter years and this has provided the perfect platform for the field of medical engineering to flourish.

The portable electrocardiogram (ECG) device designed by the CardiaTech Team and outlined in this report is one such example of simple engineering techniques being employed to assist medical professionals in delivering high quality care while also improving the quality of life for patients. The prototype has been developed to answer the need for limiting lengthy and/or frequent hospital visits for elderly or remotely located heart patients while maintaining reliable cardiac monitoring by medical professionals. It uses the basic but hardy Arduino Uno microcontroller board as a foundation with the addition of Bluetooth technology, ECG monitoring apparatuses and a display screen to create a portable, wearable heart monitoring device that is easy to use and cost effective to produce. Although the device has yet to overcome problems associated with physical size, battery life and limitations on the computing power, the benefits associated with the device's remote capabilities and the transfer of data from the device to apps and databases are encouraging and certainly compel further study and subsequent prototypes. Similar to the popularity of wearable health devices such as Fitbits and Smart Watches, there is undoubtedly both the demand and space for portable ECG devices in marketplace of this new age of digital wellness, especially where technology is able to promote a more collaborative relationship between doctor and patient without diminishing the level of care.

2.0 Introduction

Since the first clinical recordings of an electrocardiogram (ECG) developed by Willem Einthoven in 1902 (AlGhatrif & Lindsay, 2012), electrocardiography has become a quintessential part of assessing patients presenting with cardiac symptoms. Although ECG devices are commonplace and available at most hospitals, they require a patient to be connected to the device by a medical professional and monitored while the reading is taken. The reading is then evaluated by physicians and cardiologists to determine a diagnosis and treatment plan. With heart disease as the leading cause of death in Australia (Heart Foundation, 2020) and the current climate of social distancing, there is a growing demand for more portable, wireless ECG devices that transmit real time data from the patient to medical professionals regardless of location. The focus of this project was to create a wearable device that could monitor the cardio cycle of an elderly user and report any abnormalities or concerns to their doctor without needing to leave their home.

2.1 Scope

Remote ECG monitoring systems could soon be commonplace medical devices for monitoring patients within the comfort of their own homes, especially those who are elderly, frail or living in isolated locations. The prototype device must have been designed and built with accompanying code, although any additional features were optional, and had to be accomplished within the following limitations:

- Twelve weeks of design and build time
- Safe for anyone to use or come into contact with
- Device must be portable
- Device must read and interpret the cardiac cycle of the user

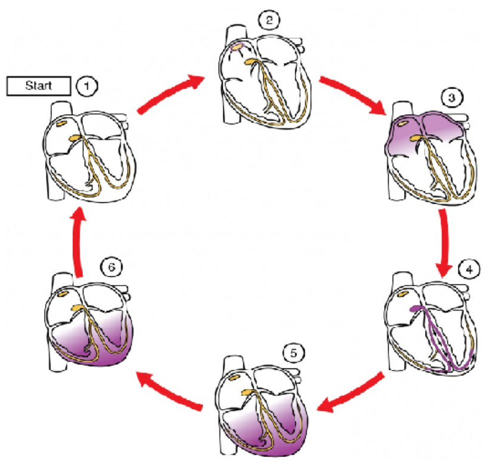
2.2 Constraints

The prototype device is limited to a network connection, meaning the user would require a wireless connection at home. Although more than 80% of Australian households have internet access (Australian Bureau of Statistics, 2018a) and would be able to use this device with ease, it is worth noting that those in remote areas who are often in need of this type of technology are also those who are less likely to have reliable internet access. Since the device is using a rechargeable battery, the user will not be able to wear the device at all times. This window of time where the patient is not being monitored will result in limited or incomplete data and potentially increase the risk of heart problems occurring. The device is limited to detecting an ECG signal and producing a heartrate in beats per minute (BPM). Other devices would have to be implemented to monitor alternative factors such as sleeping patterns, physical movement, body temperature and weight. The device is not waterproof and will need to be taken off for showers, again limiting the monitoring time for the patient. The device does not have a holder for it to be mounted to the patient, but the three long ECG leads mean that it can be placed beside them when attached.

2.3 Theory

The human heart consists of four chambers, which can be split into two upper chambers being the atria and two lower chambers being the ventricles. The two upper atria receive the blood coming into chambers, after which they contract and push the blood through the heart valves into the lower two ventricles. These lower ventricles push blood into lungs to gain oxygen and then send the oxygenated blood around the body or send blood with carbon dioxide to be exhaled. The term cardiac cycle refers to all the activities that the heart goes through during one cycle of this contracting and relaxing of the atria and ventricles, as seen in Figure 1.

This cardiac cycle is made up of five waves, outlined in Figure 2. The P wave is the first wave displayed by ECG indicating atrial depolarisation, in which an atrial contraction has occurred. The QRS complex is next and this refers to the combination of the Q, R and S waves which indicate ventricle contraction and depolarisation, as the signal is moving down the heart and the ventricles contract, the signal reaches its peak at R. The final wave is the T wave in which the heart relaxes, and ventricular repolarisation has occurred. It is also worth stating the gap between S and T is the time taken between depolarisation and repolarisation. These wave cycles are used to determine the persons beats per minute.



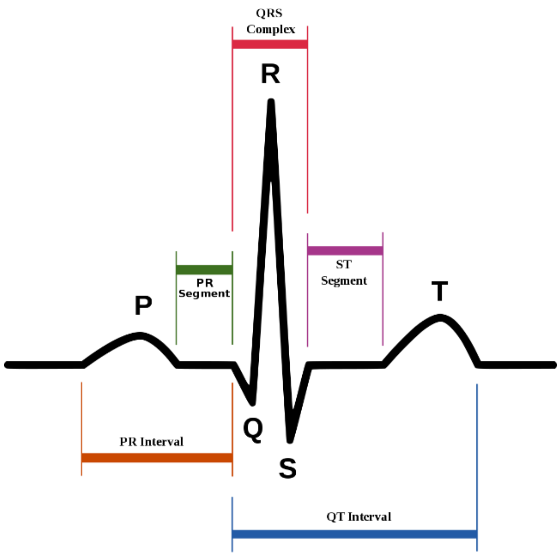


Figure 1: The cardiac cycle (Lab workshop 5)

Figure 2: The QRS complex (Wikipedia, 2020)

2.4 Components

2.4.i Arduino board

The Arduino Uno R3 development board is the main component of the prototype device and provides the processing power. Part one is the Arduino board itself, seen in Figure 3, and the other is the Prototype Shield. Together, these two pieces of hardware are connected to allow the team to upload the programs written in the Arduino integrated development environment software, while also allowing team members to connect all the hardware requirements for this project. The board for this project has five 5V input pins and five ground pins.

Figure 3: The Arduino Uno board (Unless otherwise stated, all images taken during design process by J. Cameron, 2020)

2.4.ii Battery power bank

The battery chosen for this project is a 5V power bank, seen in Figures 4 and 5, which sits inside the case. The power bank has a pre-attached 5.5mm/2.1mm centre-positive barrel plug, which will connect directly into the Arduino to provide power to it and making the unit now portable.

Figure 4: Top view of battery power bank

Figure 5: Side view of battery power bank

2.4.iii Bluetooth module serial adapter

The inspiration behind the team's decision to use the Bluetooth modules was first and foremost a consideration of the safety of all potential users of the device. For an ECG to be taken, a device must make physical contact and if it were to be connected to other devices like computers, especially if plugged into a standard 240V power supply, the user would be exposed to a potential power surge, which could cause serious harm to the user especially their heart. In simple terms, the object of the device is to help protect the heart, not expose it to greater risk, and the use of Bluetooth eliminates that potential hazard completely. The Bluetooth module, shown below in Figure 6, provides the capability to upload data to a computer or app without the need to be connected to power supply. This also comes with the added bonus of making the device portable, minimising extra cords or wires and simplifying the function of the device and the number of steps taken by the user in order to achieve the desired outcome.

Figure 6: Bluetooth module

2.4.iv Breadboard

The Breadboard component, seen in Figure 7, is key to building the circuits and connecting the electronics without needing to solder them together and is achieved by putting the components into the board's sockets and using jumper wires to connect them. This is a great cost-effective way to achieve the connectivity required without having to outlay extra costs for soldering equipment or create a situation where manufacturing mistakes could potentially be made.

Figure 7: Breadboard (Core Electronics, 2020)

2.4.v AD8232 heart monitor

The AD8232 is designed to chart the activity of the heart by extracting, amplifying, and filtering small biopotential signals in the presence of noisy conditions, such as those created by motion or remote electrode placement. The three leads plug directly into the AD8232, as shown below in Figures 8 and 9. The heart monitor converts the signal into an output number that can be charted, which will then show the ECG reading.

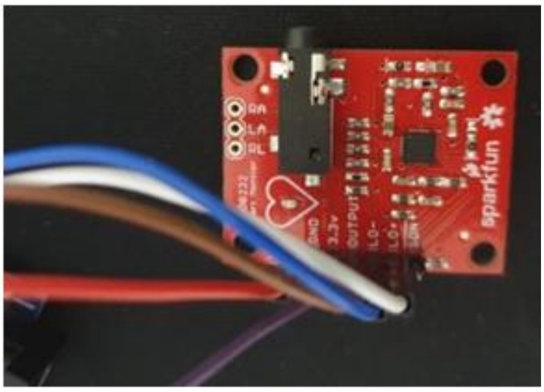


Figure 8: AD8232 heart monitor with jumper wires

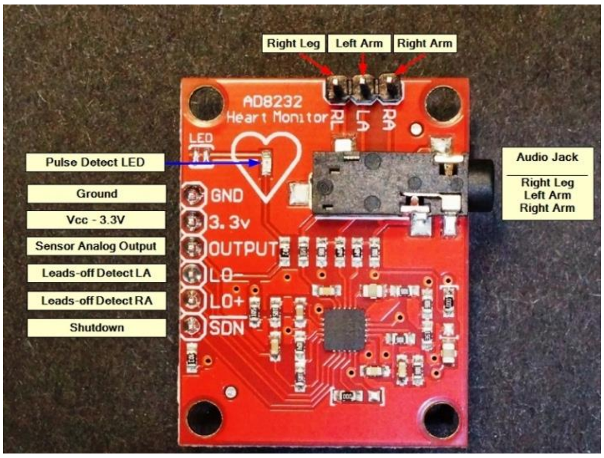


Figure 9: AD8232 heart monitor with labels (Proto Supplies, 2019)

2.4.vi Sensor lead

The sensor lead seen in Figure 10 is, at one end, plugged into the heart monitor AD8232 while the other runs out to the three leads which are clipped onto the electro pads and used to transfer the signal from the body to the device.

Figure 10: Sensor lead

2.4.vii Electro pads

Electro pads, like the one shown in Figure 11, are placed onto the body in specified locations. These pads are what detect the electrical signal created by the heart.

Figure 11: Electro pad (Emergency Medical Products, 2020)

2.4.viii Jumper wires

Jumper wires are used to wire the device allowing everything to be electrically connected via clicking in or connecting together without the need of soldering, as seen in Figure 12.

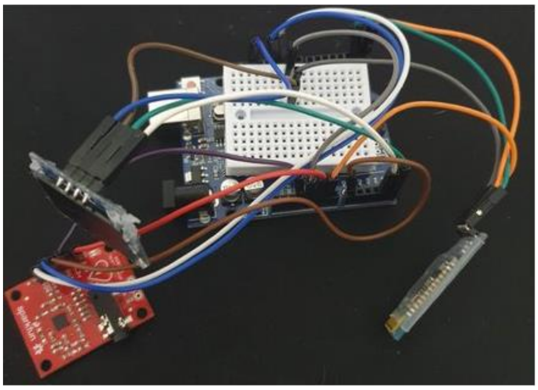


Figure 12: Jumper wires

2.4.ix OLED

The Organic Light Emitting Diode (OLED), shown in Figure 13, is display screen technology that offers bright, colourful images with a wide viewing angle. The OLED screen has low power and high contrast ratio and fast response time for showing the heart cycle or bpm of the user. These display screens are very good choice as they can display a physical representation of the user's heartrate while also being very cost effective.

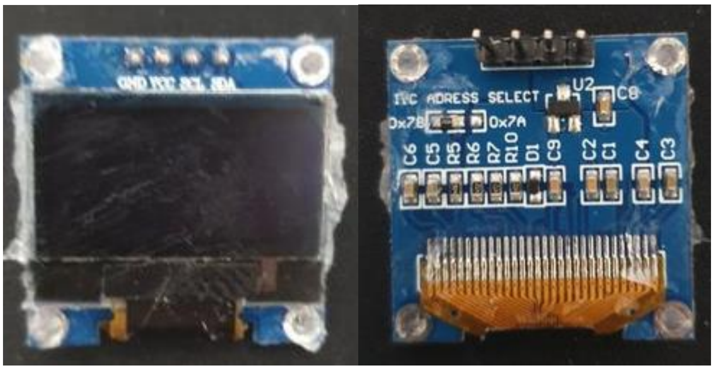


Figure 13: Front and back of OLED

2.4.x Casing

The team felt that a simple but custom-made case would be imperative to the overall design, both from the safety aspect of keeping the wires and boards out of harm's way and also from an aesthetic viewpoint. As anyone with medical conditions knows, the less intrusive and visible the device is the better the patient feels about using it. Ultimately a waterproof case would be ideal, however with time and cost constraints, the case used for this prototype was a 3D printed design that allows the device to be lightweight and non-conductive, seen in Figures 14 and 15. It also allows for the device to fit neatly inside the belt holder.

Figure 14: Top view of casing

Figure 15: Casing connections

2.4.xi Developed skills

The follow skills were learnt and developed by the CardiaTech Team throughout this project:

- Using Arduino Uno and other hardware components
- Learning software style of Arduino's sketch
- Learning to not force ideas but allow them to flow organically and always make time to revaluate ideas along the process

- Understanding the design thinking process
- Taking responsibility for failures and celebrating successes
- Effective time management, as both individuals and as a team
- Seeing a project through from beginning to completion maintaining determination in tough circumstances, such as the restrictions in place due to the Covid-19 outbreak

3.0 Design Process

3.1 Assumptions

The assumptions associated with the development of this prototype are based on the device working perfectly with all surrounding variables being ideal. It assumes the patient is willing to wear the device as much as possible and able to integrate the monitor into their lives. The patient having a constant internet connection is assumed as wireless internet connection is vital to the effectiveness of the device. It assumes that a monitoring nurse or practitioner will be available at hourly intervals to receive updates of changes in the patient's heart that could be evidence of cardiac events. Since the typical patients are either elderly or frail it is assumed that they will not be participating in high intensity physical activity, giving them limited reason for having a raised heart rate. Since the battery has a limited charge it is assumed that the patient will regularly charge the battery, meaning the device would have no complications in performing its tasks.

3.2 Initial design

The initial hardware design of the wireless ECG device was intended to be used for a target audience of 60 years of age and older to monitor heart health at home. The device was originally powered by a USB cable to a computer, but the team chose to power the Arduino Uno device with a rechargeable 9V battery. The breadboard provided was used to connect all of the components with wiring but without any need for soldering. The team added the Bluetooth hc05 module connected to the Arduino breadboard, allowing the data to be transferred and displayed on other devices without the risk of power surges or electrocution to the user. Once other components were attached, such as the heart monitor Sparkfun AD8232 unit and leads and pads, the team was able to test the unit and collect heart data. In order to attach the device's electrodes to get the data, a nonwoven fabric material was chosen. This is a type of breathable paper cotton with silver chloride gel which will give the user comfort as well as good conductive contact. The wires that connect the ECG unit to electro pads were still to be decided regarding length and placement on where to attach to the casing or device. The OLED SSD1306 display screen was added to the design to display the current heartrate to the users, giving some measure of information and inclusion into their own heart health.

One of the most difficult design elements in this process was the external casing which would determine how the components fit together. Initial thoughts included a holder that could hang around the user's neck like a lanyard, however the relatively large size of the device is problematic. Another option was a plastic Toyogiken junction box that would house all of the components and wiring and protect it from water or moisture and also be light weight and easy to carry, however the practicality of this box and how it would be carried was difficult to determine.

3.3 Final design

The final design of the wireless ECG device was still intended to be used for the target audience of sixty years of age and older to monitor heart health at home. The following milestones were achieved in the lead up to the due date:

- Device is portable
- Bluetooth successfully allows data to be transferred and uploaded
- The app registers health checks and a bpm from the device but had a slight delay in doing so
- The battery works and is able to be recharged
- The OLED displays the bpm of the user
- The device fits correctly and comfortably inside the casing

The final design still had many issues displaying the minimum and maximum heart rate, however the team found that this was due to a coding logical conditional error that would be easy to fix. A second issue was when attempts were made to display the heart signal, the P wave was not being detected. The team found that there may be contact issues with the electro pads which, with additional time and funding, would be exchanged for higher quality pads that come with a conducting gel to produce a better signal. The team also needed to add more smoothing points for the signal to make it clearer as they found that three points were insufficient and the six points used in standard ECG devices would be more effective and therefore preferable, despite the possible lessening of comfort for the user. An example of the signal successfully sent by the device can be seen in Figure 16 and the final design with casing can be seen in Figures 17 to 19 below.

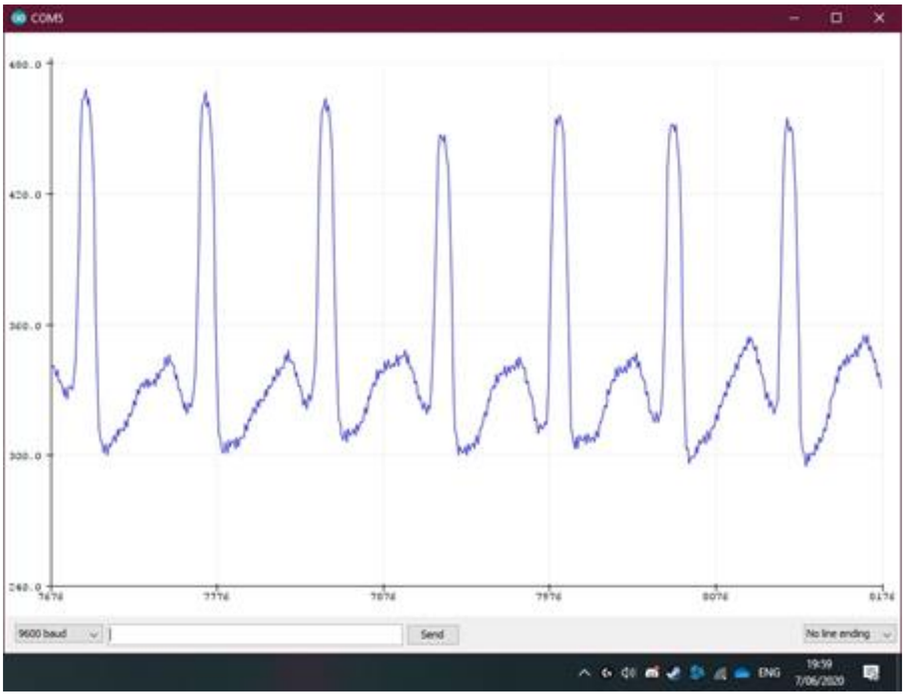


Figure 16: ECG signal

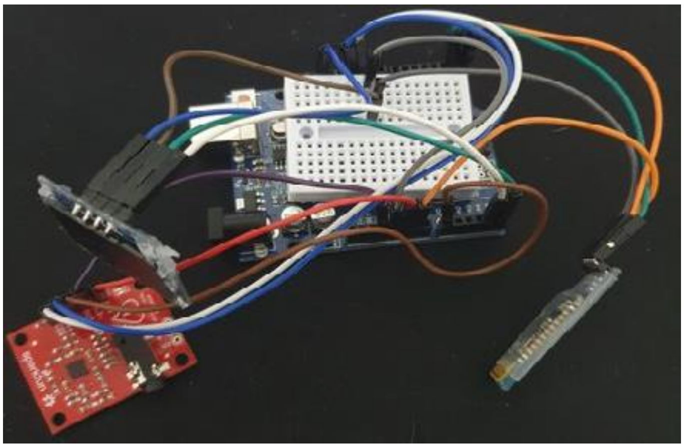


Figure 17: Completed device outside casing

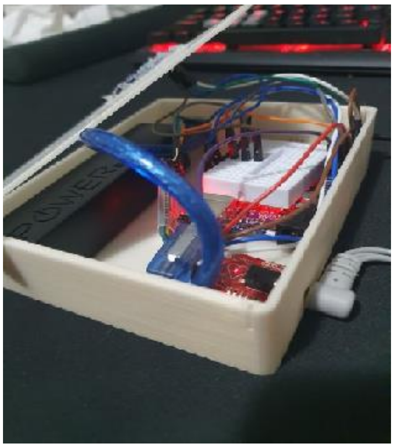


Figure 18: Completed device with casing

Figure 19: Working OLED display

3.4 Cost

A strong selling point for this prototype device was its ability to be low cost to the user. This was a primary focus for the team, as the target demographic in Australia will undoubtedly include those receiving the aged pension at a basic rate of $860.60 per fortnight (Services Australia, 2020). For those senior Australians not reliant on the aged pension, they are still more likely to be asset rich, in that they own their own home, but cash poor with little left to spend (Penfold, 2019). The good news for devices such as this prototype is that medical care and health related expenses feature as one of the top five categories where senior Australians are willing to spend their heard-earned and frugally saved retirement funds (WebAlive, 2020). A breakdown of the costings for the final prototype can be seen in Figure 20.

Part Item	**Price per 1 unit**	**Price per 100 unit**
AD8232 Heart Monitor	$19.95	$16.96
Sensor cables	$4.95	$4.46
Jumper wires	$5.95	$4.50
Arduino Uno R3 unit	$4.48	$3.73
Breadboard & shield	$1.39	$1.10
Electropads	$0.85	$0.20
Battery	$6.00	$6.00
Oled	$3.80	$3.42
Bluetooth Module	$5.20	$4.15
Casing	$20	$20
Accessory carry belt	N/A Can not buy in individually	$33
	Total cost price for 1 unit **$74.27**	**Total cost pric per 100 units** **$64.92**
	Retailing device only	**$119.00**
	Retailing device and Belt holder	**$159.95**
	Retailing Belt holder	**$42.95**

Figure 20: Table of costings for the prototype device

3.5 App development

During this project, the team always had the idea of creating and building an app that would allow for remote monitoring. The software used for this skeleton app design was MIT App Inventor, with several functions seen in Figure 21 below.

The app can successfully:

- Monitor the user's heart and alert their doctor of any abnormal heart functions
- Record cardiac cycle constantly and send that data to Microsoft Excel spreadsheets for later use if required, see Figure 22 which includes the date and timestamp of the data collected
- Send the user notifications about regular health checks that they may need throughout the year
- Show the user in real time what is being displayed on the OLED display so the user can look at their phone and leave the device in its pouch if they desire to do so

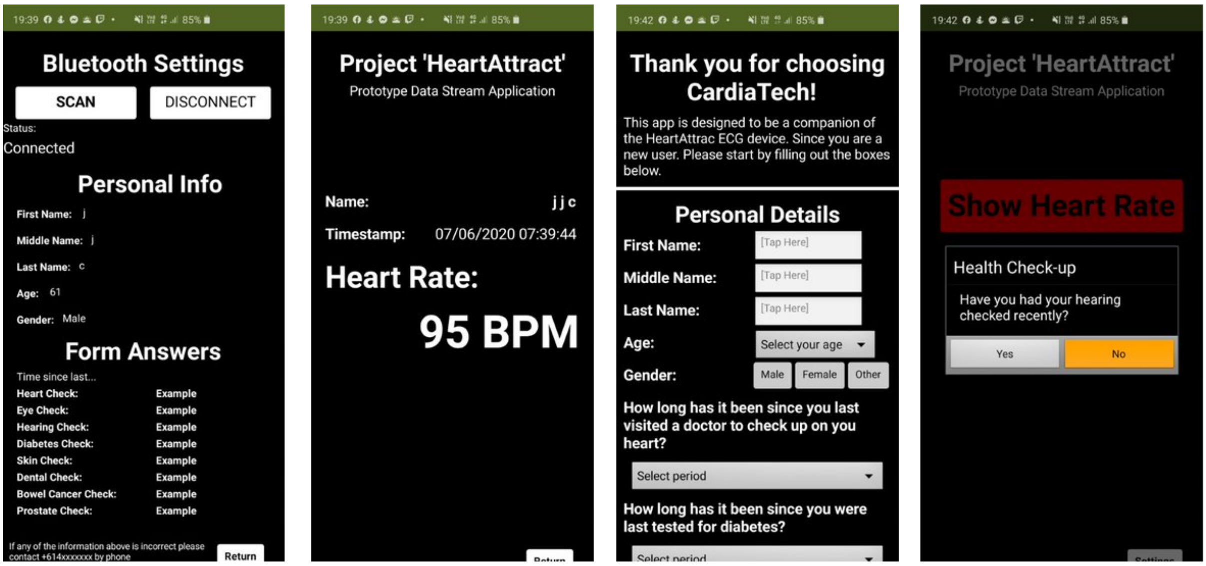


Figure 21: Current functions of the CardiaTech heart monitoring app

The CardiaTech Team also felt that the app showed good business potential as access could be included for the user in the purchase of the device but sold with a subscription fee to the public and private medical sectors, which would allow doctors and medical teams to access the user's information and heart history. This subscription-based access would create an additional revenue stream for future developments and upgrades, as well as increasing the attractiveness and financial viability for investors.

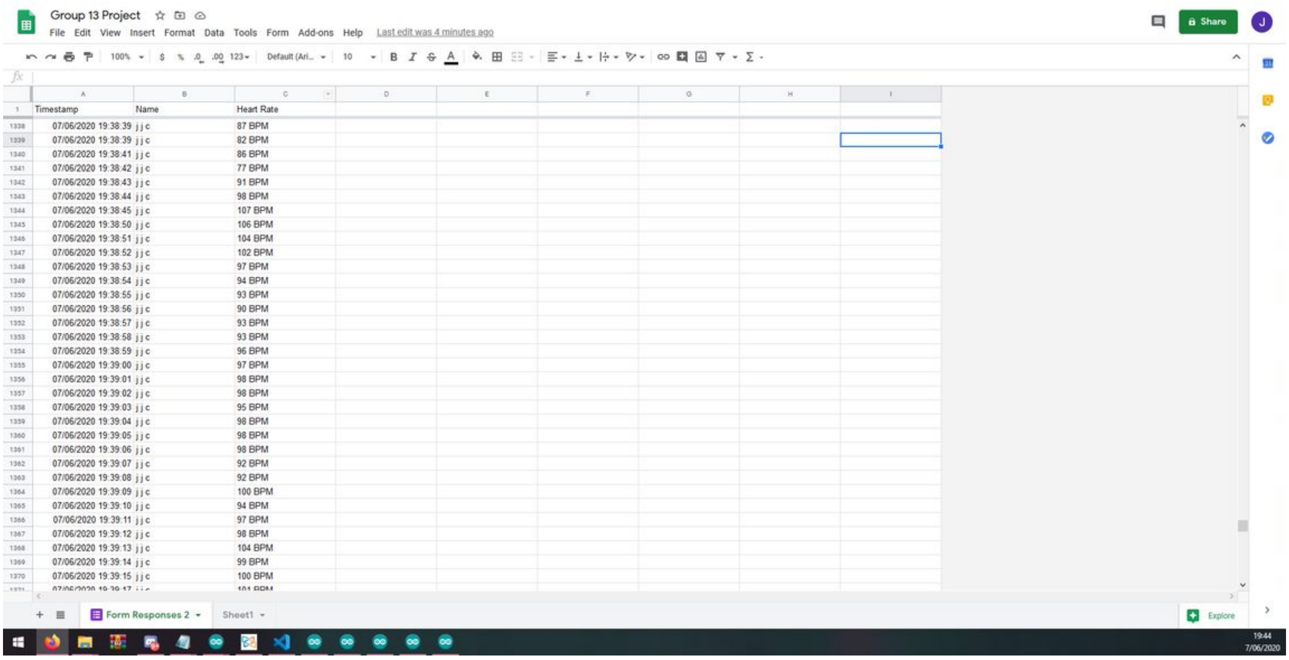


Figure 22: Date and timestamped BMP Excel spreadsheet uploaded from app

3.6 Pouch holder

The CardiaTech Team had always hoped to make the device portable not only in name but also in function and the pouch holder, seen in Figure 23, was design and inspired by musical theatre audio setups that performers used on stage. Although the team had originally planned on creating an arm band, the size of the device was predetermined to a degree by the mandatory use of the Arduino Uno and therefore was too large to comfortably wear on the arm. The pouch belt, worn securely around the waist, is comfortable, safe and nonconductive without restricting the general range of motion. This was a great solution to allow the users to go about their daily lives with minimal impact and maximum peace of mind for the security of the device and the user alike.

Figure 23: Pouch holder (Bishop Audio and Lighting, 2018)

3.7 Device improvements

Following testing of the final prototype device, the team found that many improvements would be required before it could be considered ready to bring to market.

These improvements include:

- Finding better quality case as a 3D printed case proved to be not as durable as first thought
- Making BPM readings be more accurate with better coding logic and stricter threshold designing.
- Giving the device a more powerful micro-controller allowing the team to reduce the size drastically and allow more computing power
- Upgrade the OLED display to allow for better visuals for the user, especially those with low or declining vision
- Improving the way the team calibrates the device as prototype was delayed in the reading of the BPM and sometimes displayed a few random readings before reverting back to normal

- Making the device water resistant as no precautions were put into place to deal with the likelihood of inadvertent contact with water within a daily routine, such as the user touching the device after washing dishes or even entering a bathroom with residual steam from a hot shower.

4.0 Evaluation

Following the testing of the prototype device, it was natural for the CardiaTech Team to reflect on those areas of the project that had not gone to plan, such as the poor quality of the 3D printed case, the irregular displays of minimum and maximum BPM and the difficulties surrounding detection of the P wave on the display. The team hypothesises that this is likely due to a calibration issue regarding the thresholds and was also advised that the device should have included more points in the signal smoothing. Unfortunately, in doing so at this end stage the signal actually deteriorated, so further investigation in this area would be essential.

However, the device is not wholly without merit. One of the team's great achievements was the creation of the skeleton version of the app as well as the success in transferring data taken from the Arduino Uno and uploading this to Microsoft Excel spreadsheets. The device was also successfully made portable, wearable and easy to use despite the size of the mandated components.

Although the team considers the prototype device somewhat of a disappointment, there were undoubtedly some positive and noteworthy concepts developed that worked to plan and could be very useful in future designs.

5.0 Conclusion

This prototype device is a great concept idea and demonstrates that innovation in the area of medical engineering need not to be limited to professional medical engineers but that even the average student can access the parts required to help design and build useful and practical devices. There is also no doubt that this arena of digital wellness is a growing industry with a ready-made demographic of pre-existing patients, which provides a fertile ground for medical engineering students to develop and flourish and one that could be equally attractive to investors.

Although the device requires further refining and certain aspects would need to be redesigned to make the device perform at the expected and required level, the lessons learnt throughout this process have been invaluable and the team has not walked away empty-handed. While the social distancing restrictions associated with the Covid-19 pandemic certainly played a part in creating additional hurdles in the progression of this project, it was these very difficulties that forced the team to think outside of the box and step outside of their comfort zone in the way that they interacted and worked as a team. This might well have been the very best lesson learnt and one that will, no doubt, stand them in good stead for the future. For what is engineering but the use of technology to find an innovative solution to an unforeseen obstacle.

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7.0 Appendix A

7.1 Project related questions

1. "Our team operated well". Discuss actions your team performed well and actions it performed poorly. – Strongly agree.

I would say our team performed well as a unit throughout the course, everyone was very respectful and committed to the project. Great leadership was shown, and everyone always checked their ego at the door. Being apart of this team was a great experience. Due to current circumstances of Covid-19 not being able to work with hardware as a team was our downfall as it put all the pressure on one person to build the unit.

2. "Our team communicated well". Do you believe, in this case, that communication was important to succeeding in your project? – Strongly agree

Communication was crucial especially in this climate not being able to meet up. Our communication was very good over the time of this course and everyone was easy to get a hold of when needed.

3. Do you think that you, personally, where a useful team member? How could you have been a more useful team member? – Agree

I believe I was a useful team member throughout the project doing all various tasks required of me overseeing communications, logistics and coding assistant. I could of achieved a lot more but due to schools being closed I have had my daughter home full time over last 8 weeks and looking after her and keeping her education going definitely hindered my ability to achieve a higher standard or greater volume of tasks.

4. Given an additional 2 h a week of workshop time do you believe you could have achieved more as an individual than your team did? If you answer "yes" explain why, and what you could have done better from a team management perspective. – Disagree

Three people are always better than one and more time does not always mean better ideas, or a smoother process is achieved.

5. Discuss any other elements of your team's operation as required. Did you have any outstanding team members or interesting team dynamics? Is there anything useful you have learned that you will take with you into future team-based experiences?

Being thirty-three years old and back at university I would like to give credit to William Cheney for demonstrating great leadership with ideas and plans on where we can take this project. And to Jaydon Cameron for his ability to be lumped with all the hardware and do what he did with it. The lessons I have taken away from this experience is any project or situation can be flipped on its head at any point and you need to adapt and overcome the challenges that are created if you want to be successful, But I have also noticed there are lot of bright kids coming through our education system and I think our future is looking bright in the medical device field.

6. If you could start again what is one thing you would do differently?

I would completely redesign our pitch as it was terrible.

7. If you could give one piece of advice to a student next year, what would it be?

Start designing from week one, have a discussion with the team and find out strengths and weaknesses of team members and what resources they might have access to so it makes the process more efficient.

8. If you could change 1 thing about ENGG1500 what would it be?

I would like to see each member of each team be given the standard kit so everyone can work on the project at home and if parts break you have backups available.

7.2 Personal professional development questions

I feel completely comfortable at university. - Disagree.

I am excited about my university degree. - Strongly agree.

I am confident in my mathematical ability. - Agree

I am confident in my scientific ability. - Agree

I feel confident in my communication skills. - Strongly agree.

I would consider myself to have effective oral and written communication skills in professional and lay domains. - Strongly agree.

I would consider myself to have a creative, innovative, and pro-active demeanour. - Agree.

I would consider myself to understand and be able to perform the application of established engineering methods to complex engineering problem solving. - Agree.

I would consider myself to understand and be able to perform the application of systematic engineering synthesis and design process. – Agree

I would consider myself to have knowledge of contextual factors impacting the engineering discipline – Agree

I would consider myself to have an understanding of the scope principles, norms, accountabilities, and bounds of contemporary engineering practice in the specific discipline.

- Agree

7.3 Comment required questions

1. What is one of your strengths that you think will help you as an engineer?

My strong work ethic and attitude about putting in the work.

2. What is the one thing you would like to improve that you believe will make you a better engineer?

My ability to be more comfortable in academic settings as I am very use to being a leader in my former trade but changing careers and doing university has been challenging.

3. Would you like to make any comments on any of the questions, the course or engineering degree in general?

Being a newly established degree especially with computing, is there good chances of employment with medical computing engineering or should I just be doing software engineering?

4. How long did this reflective component take you?

One hour.